CHAPTER 7

BIOENERGETICS

MULTIPLE CHOICE QUESTIONS

1. **The loss of electrons is called:**
(a) Reduction (b) Oxidation (c) Redox (d) None of these
2. **Who discovered ATP?**
(a) Fritz Lipmann (b) Karl Lohmann (c) Malvin Calvin (d) Louis Pasteur
3. **When was ATP discovered?**
(a) 1923 (b) 1925 (c) 1927 (d) 1929
4. **The ATP was proposed to be the main energy transfer molecule in the cell by:**
(a) Fritz Lipmann (b) Karl Lohmann (c) Malvin Calvin (d) Louis Pasteur
5. **How much energy is released by the breaking of phosphate bond of ATP?**
(a) 7100 calories (b) 7200 calories (c) 7300 calories (d) 7400 calories
6. **When one inorganic phosphate is detached from ATP, it is converted into:**
(a) ADP (b) AMP (c) Both a & b (d) None of these
7. **NADPH is formed during:**
(a) Light reactions (b) Dark reactions (c) Both a & b (d) None of these
8. **The break down of water molecule during light reactions is called:**
(a) Glycolysis (b) Kreb's Cycle (c) ETC (d) Photolysis
9. **The whole series of light reactions is called:**
(a) N-scheme (b) M-scheme (c) O-scheme (d) Z-scheme
10. **Photosynthetic pigments are arranged in the form of:**
(a) Carotenoids (b) Chlorophyll-a (c) Chlorophyll-b (d) Photosystems
11. **Main photosynthetic pigment:**
(a) Carotenoids (b) Chlorophyll-a (c) Chlorophyll-b (d) None of these
12. **When was Calvin awarded Nobel Prize?**
(a) 1960 (b) 1961 (c) 1962 (d) 1963
13. **Which one factor does not affect the rate of photosynthesis?**
(a) Light (b) Temperature (c) Humidity (d) CO_2
14. **In cellular respiration, food is oxidized to:**
(a) CO_2 (b) H_2O (c) Both a & b (d) None of these
15. **Soy sauce is made by the fermentation of:**
(a) *Rhizopus* (b) *Penicillium* (c) *Aspergillus* (d) *Allium cepa*
16. **How many stages are present in aerobic respiration?**
(a) 1 (b) 2 (c) 3 (d) 4
17. **How many ATP molecules are generated in aerobic respiration?**
(a) 2 (b) 24 (c) 34 (d) 36

ANSWERS:

1	b	2	b	3	d	4	a	5	c
6	a	7	a	8	d	9	d	10	d
11	b	12	b	13	c	14	a	15	c
16	c	17	d	18	b				

SHORT QUESTIONS

Q. No. 1 How do cells work like an open system?

CELLS AS OPEN SYSTEMS

A living cell exhibits ceaseless chemical activities. Cells are like open systems, i.e.

- Substances are entering and leaving the cell all the time.
- Inside the cells, substances are broken down and new substances are formed.

Q. No. 2 In how many forms does energy exist in living organisms?

FORMS OF ENERGY IN LIVING ORGANISMS

Energy drives all processes occurring in a cell. In living organisms, energy exists in two forms:

- **Kinetic energy** is actively involved in doing work
- **Potential energy** is stored for future use.

Potential energy is stored in chemical bonds, and is released as Kinetic energy when these bonds break.

Q. No. 3 Define bioenergetics.

BIOENERGETICS

The study of energy relationships and energy transformations (conversions) in living organisms is called bioenergetics.

Q. No. 4 How do organisms obtain energy? Or Discuss inter-conversion of energy in living organisms.

Energy Gain:

Organisms obtain energy by metabolizing the food they eat or prepare.

Inter-conversion of Energy:

- Food contains potential energy in its bonds. When these bonds are broken down, a large amount of kinetic energy is usually released.
- Some of this energy is stored in the form of potential energy in the bonds of ATP molecules while the rest escapes as heat.
- The potential energy stored in ATP is again transformed into kinetic energy to carry out life activities.

Q. No. 5 What is NAD^+?

NICOTINAMIDE ADENINE DINUCLEOTIDE (NAD^+)

Nicotinamide adenine dinucleotide (NAD^+) is a co-enzyme which takes electrons and hydrogen ions and is thus reduced to NADH. One form of this co-enzyme carries phosphate with it, so it is called $NADP^+$.

Q. No. 6 In dark reactions, 3-carbon compounds are reduced to form carbohydrates. What is the ultimate source of hydrogen for this reduction?

Water

Q. No. 7 What are pigments?

PIGMENTS

Pigments are the substances which absorb visible light. Different pigments absorb light of different wavelengths (colours).

Q. No. 8 What is FAD?

FAD

Flavin adenine dinucleotide (FAD) is a co-enzyme like NAD^+. It gets two hydrogen and reduces to $FADH_2$.

Q. No. 9 Why is it incorrect to say that the energy-releasing step of respiration is the electron transport chain?

Energy is released in glycolysis and Krebs cycle in the form of NADH and $FADH_2$. electron transport chain transforms the energy present in these compounds to ATP.

Q. No. 10 Why Krebs cycle is named so?

NAMING KREBS CYCLE

A British Biochemist, Sir Hans Krebs discovered this series of reactions that is why it is called Krebs cycle.

Q. No. 11 There are more chloroplasts in the palisade mesophyll than spongy mesophyll, why?

MORE CHLOROPLASTS IN PALISADE MESOPHYLL

There are more chloroplasts in the palisade mesophyll than spongy mesophyll because the palisade cells are on the upper surface and receive more light, so they contain more chloroplasts to be able to absorb more light.

Q. No. 12 What happens in cellular respiration?

In cellular respiration, food is oxidized CO_2 while O_2 is reduced into H_2O.

LONG QUESTIONS

Q. No. 1 Discuss energy transformations in living organisms.

ENERGY TRANSFORMATIONS IN LIVING ORGANISMS

Organisms obtain energy by metabolizing the food they eat or prepare. Food contains potential energy in its bonds. When these bonds are broken down, a large amount of kinetic energy is usualy released. Some of this energy is stored in the form of potential energy in the bonds of ATP molecules while the rest escapes as heat. The potential energy stored in ATP is again transformed into kinetic energy to carry out life activities.

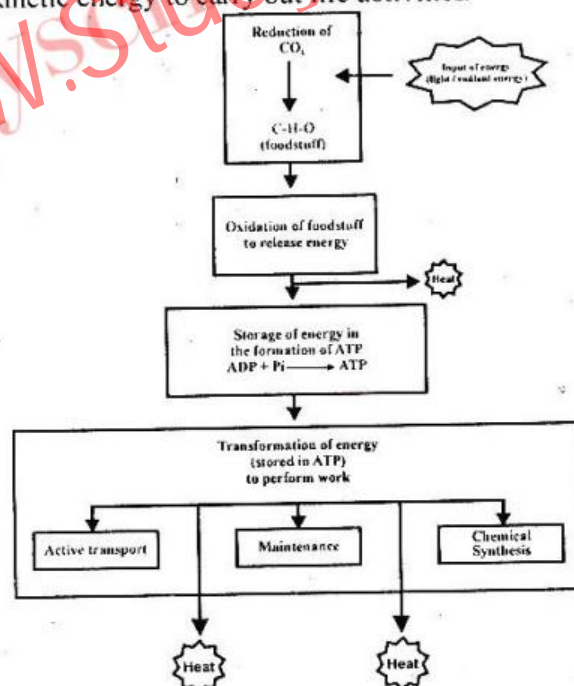



Figure: Energy Transformations in Living Organisms

Q. No. 2 **Write a note on Oxidation –Reduction Reactions.**

OXIDATION-REDUCTION REACTIONS

Oxidation:

The loss of electrons is called oxidation.

Reduction:

The gain of electrons is called reduction.

Redox Reactions:

The reactions which involve the loss and gain of electrons are called oxidation-reduction or redox reactions.

Electrons as Source of Energy:

Electrons can be an energy source. It depends upon their location and arrangement of atoms. They can form two types of associations:

1. Stable association
2. Unstable association

1. Stable Association:

When electrons make a stable association, they are not a good energy source. For example, electrons in oxygen atom.

2. Unstable Association:

When electrons make an unstable association, they are good sources of energy. When they are dragged away from oxygen and attached to some other atom, e.g. carbon or hydrogen, they make an unstable association. They try to move back to oxygen and when this happens, energy is released.

Redox Reactions in Living Organisms:

In living organisms, redox reactions involve the loss and gain of hydrogen atoms. A hydrogen atom contains one proton and one electron. It means that when a molecule loses a hydrogen atom, it actually loses an electron (oxidation). Similarly, when a molecule gains a hydrogen atom, it actually gains an electron (reduction).

Requirement of Energy Flow:

Various life processes in organisms involve constant flow of energy. This energy flow comprises the acquisition and transformation of energy.

Use of Energy:

The energy is used for various life processes like:

- Growth
- Movement
- Reproduction

SHORT QUESTIONS

(1) Define 'Co-factor' and 'Co-enzyme'.

Consult Long Question No. 2

(2) What is the main use of enzymes in paper industry?

Consult Long Question No. 3

THE TERMS TO KNOW

Activation energy: The minimum energy required to start a reaction.

Active site: A small portion of the enzyme involved in catalysis, which recognizes the substrate, binds it, and carries out the reaction

Amylase: An enzyme to breakdown starch and glycogen into simple sugars

Biocatalyst: Another name for an enzyme, a substance that catalyzes biological reactions

Catabolism: The type of metabolism which is degradative, i.e. breaks down larger complex molecules into simpler ones

Catalyst: Ansubstance that increases the rate of a chemical reaction without itself undergoing any permanent chemical change.

Coenzyme: An organic cofactor which is loosely bound to the enzyme

Cofactor: Non-protein molecules or ions required by some enzymes for functioning. They can be organic (e.g. Flavin & Heme), or inorganic (e.g.metal ions).

Denaturation: The destruction of an enzyme's molecular structure as a result of higher temperatures than optimum, causing retardation and complete blockage of enzyme activity.

Optimum pH: All enzymes work at their maximum rate in a narrow range of pH, called as the 'Optimum pH'. Every enzyme has its specific optimum pH value.

Optimum temperature: Every enzyme works at its maximum rate at a specific temperature which is called 'Optimum Temperature' for that enzyme.

Enzyme: Poteins that catalyze (i.e. speed up) biochemical reactions and are not changed during the reaction

Enzyme-substrate complex: A temporary attachment of a substrate to an enzyme at its active site, which results in a reaction and formation of products

Lipase: An enzyme which catalyzes lipids into fatty acids and glycerol

Lock-and-Key model: A model for enzyme action proposed by Emil Fischer which states that bth enzyme and substrate possess specific shapes that fit exactly into one another.

Metabolism: Metabolism is a set of biochemical reactions that occur in living organisms in order to maintain life.

Product: The substances formed as a result of action of an enzyme on a substrate

Saturation: The occupation of all active sites of all the available enzyme molecules which results in a constant rate of reaction

Substrate: The substance on which an enzyme acts.

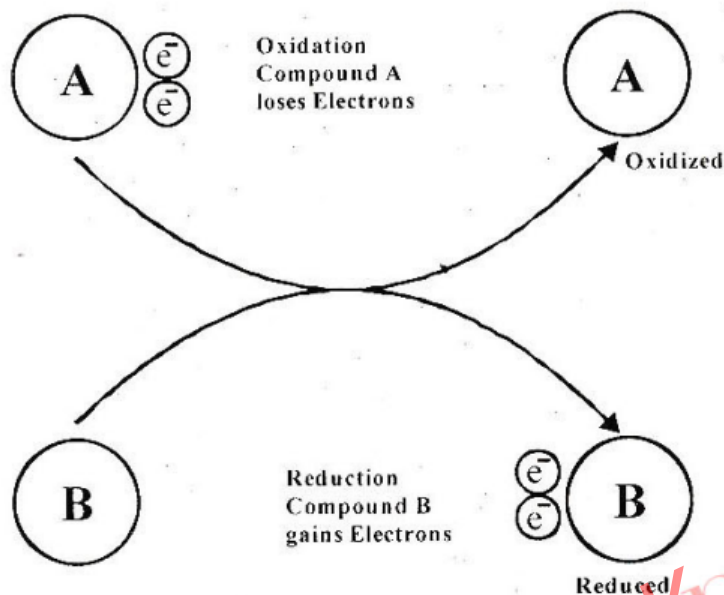



Figure: Redox Reactions

Q. No. 3 Write a note on ATP.

ATP: THE CELL'S ENERGY CURRENCY

Introduction:

The major energy currency of all cells is a nucleotide called adenosine triphosphate (ATP).

Discovery:

ATP was discovered in 1929 by Karl Lohmann.

Work of Fritz Lipmann:

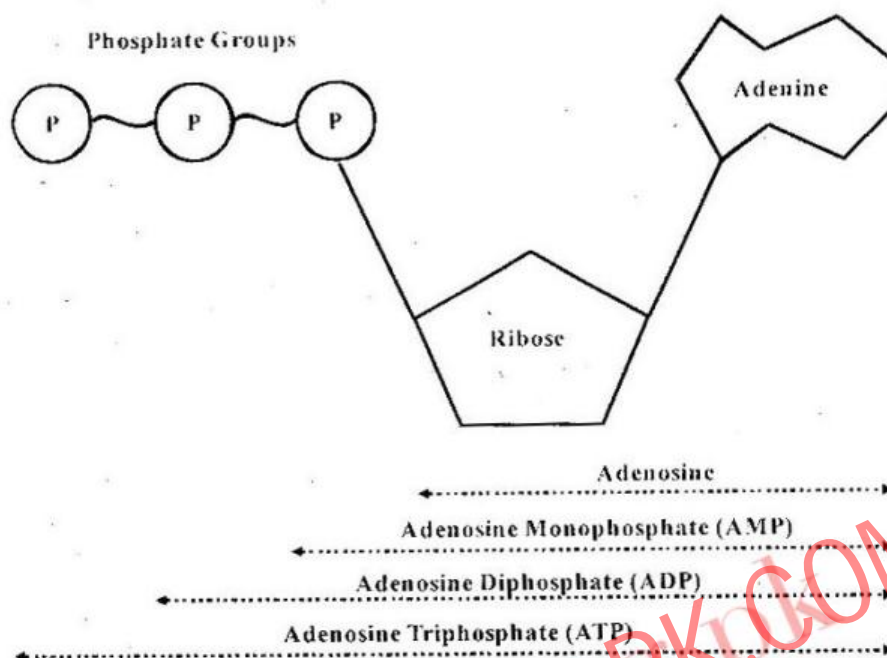
In 1941, Fritz Lipmann proposed ATP to be the main energy-transfer molecule in the cell. He was awarded Nobel Prize.

Significance:

ATP is the main energy source for majority of the cellular functions like:

- Synthesis of macromolecules (DNA, RNA, proteins)
- Movement
- Transmission of nerve impulses
- Active transport
- Exocytosis
- Endocytosis

Appearance of ATP:

Because ATP plays a central role as energy currency in all organisms, it must have appeared in the early history of life.

Molecular Structure of ATP:

The ability of ATP to store and release energy is due to its molecular structure.

ATP molecule has three subunits:

i. Adenine (a double-ringed nitrogenous base)
ii. Ribose (a five-carbon sugar)
iii. Three phosphate groups in a linear chain

Representation:

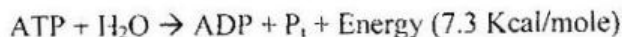
The covalent bond connecting two phosphates is indicated by 'tilde' (~) and is a high energy bond.

Energy Release:

The energy in this bond is released as it breaks and inorganic phosphate (Pi) gets separated from ATP.

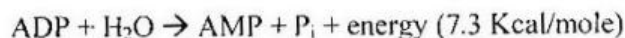
Breakdown of ATP:

The breaking of one phosphate bond releases about 7.3 Kcal (7,300 calories) per mole of ATP as follows:

$$ATP + H_2O \rightarrow ADP + P_i + \text{Energy (7.3 Kcal/mole)}$$

In common energy reactions, only the outermost of the two high-energy bonds breaks. When this happens, ATP becomes ADP (adenosine diphosphate) and one Pi is released.

Breakdown of ADP:

In some cases, ADP is further broken down to AMP (adenosine monophosphate) and Pi as follows:

$$ADP + H_2O \rightarrow AMP + P_i + \text{energy (7.3 Kcal/mole)}$$

Synthesis of ATP:

Cells constantly recycle ADP by recombining it with Pi to form ATP. The synthesis of ATP from ADP and Pi requires the expenditure of 7.3 kcal of energy per mole. This energy is obtained from the oxidation of foodstuff.

Energy Transfer in Metabolic Reactions:

ATP is generated by energy-releasing processes and is broken down by energy-consuming processes. In this way, ATP transfers energy between metabolic reactions.

Energy Storage:

When cells use energy to build ATP from ADP, or ADP from AMP, they are storing energy as we put money in a bank.

Q. No. 4 What is photosynthesis? Explain intake of water and carbon dioxide.

PHOTOSYNTHESIS

Definition:

The process of synthesis of glucose from carbon dioxide and water in the presence of sunlight and chlorophyll, with oxygen as a by-product is called as photosynthesis.

Anabolism:

Photosynthesis is an important anabolic (building) process. It comprises many coordinated biochemical reactions.

Importance:

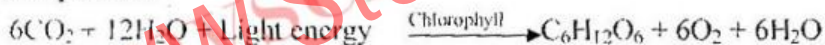
- It is an important component of bioenergetics in living systems.
- It is the most important biochemical pathway and nearly all life depends on it.

Photosynthetic Organisms:

Photosynthesis occur in:

- Plants
- Some protists (algae)
- Some bacteria

General Equation:

$$6CO_2 + 12H_2O + \text{Light energy} \xrightarrow{\text{Chlorophyll}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

INTAKE OF WATER & CARBONDIOXIDE

Raw materials for photosynthesis

Water and carbon dioxide are the raw materials for photosynthesis. Plants have mechanisms for the intake and transport of these raw materials.

Intake of Water:

Water, present in soil, is absorbed by root and root hairs through osmosis. This water is eventually transported to the leaves through xylem vessels.

Intake of Carbon dioxide:

The air that enters leaf through tiny pores (stomata) reaches into the air spaces present around mesophyll cells. This air carries CO_2, which gets absorbed in the thin layer of water surrounding mesophyll cells. From here, the carbon dioxide diffuses into mesophyll cells.

Role of Stomata:

Stomata cover only 1-2% of the leaf surface but they allow much air to pass through them.

Q. No. 5 Write a note on mechanism of photosynthesis.

MECHANISM OF PHOTOSYNTHESIS

Photosynthesis occurs in two phases:

i. **Light Phase:** The reactions which require light. They are also called "Z-Scheme'.

ii. **Dark Phase:** The reactions which do not require light. They are also called 'Calvin's Cycle'.

Formation of High Energy Molecules:
During first phase, light energy is captured and is used to make high energy molecules (ATP and NADPH).

Light Reactions: These reactions are known as light reactions.

Site of Occurrence: These reactions take place on the thylakoid membranes of chloroplasts.

Formation of Glucose:
During second phase, carbon dioxide is reduced to make glucose. In this phase, the energy from high energy molecules (ATP and NADPH) is utilized.

Dark Reactions: Since these reactions do not use light directly, these are known as dark reactions.

Site of Occurrence: The dark reactions take place in the stroma of the chloroplasts.

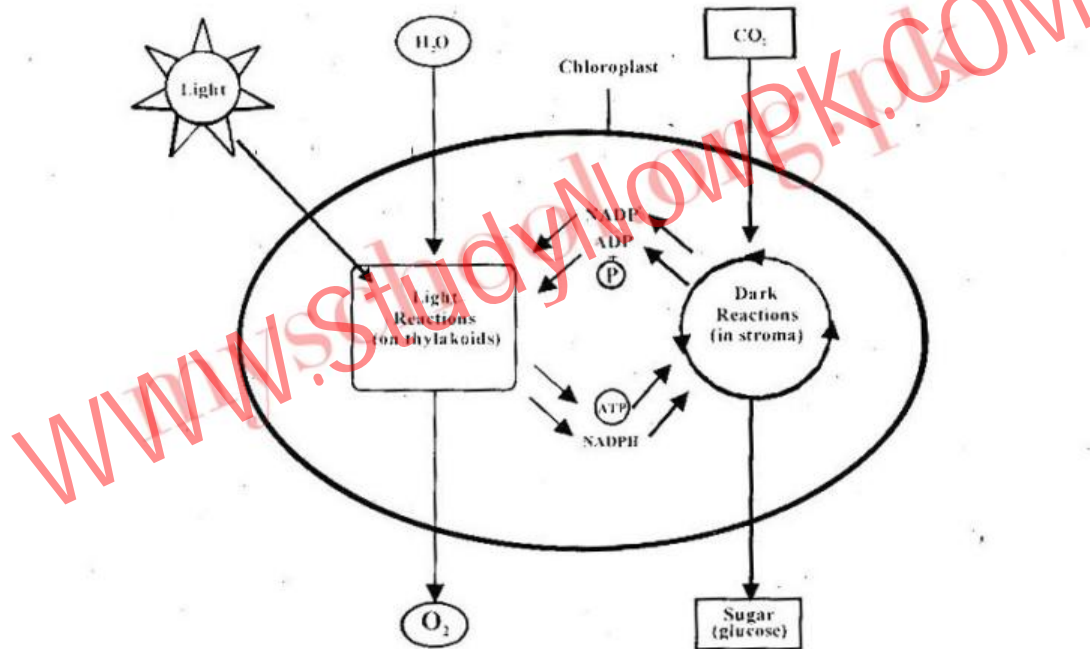



Figure: Summary of Photosynthesis

Q. No. 6 Write a note on light reactions.

LIGHT REACTIONS

Site of Occurrence: These light reactions take place on the thylakoid membranes of chloroplasts.

Mechanism:

Emission of Electrons: When chlorophyll molecules absorb light, their energy level increases and their electrons are emitted.

Synthesis of ATP: Electrons are passed to electron transport chain to produce ATP.

Formation of 3-C Carbohydrates:

The 3-carbon compounds are reduced to 3-carbon carbohydrates by using ATP and hydrogen from NADPH. The 3-carbon carbohydrates are used to manufacture glucose.

Regeneration of 5-C Compounds:

The 3-carbon carbohydrates are also used to generate the original 5-carbon compounds. This step also utilizes ATP.

Figure: Dark Reactions of Photosynthesis
(The Calvin Cycle)

Q. No. 8 Discuss role of chlorophyll and light in photosynthesis.

ROLE OF CHLOROPHYLL AND LIGHT

Absorption of Sunlight Energy:

Sunlight energy is absorbed by chlorophyll. It is then converted into chemical energy, which drives the photosynthetic process.

Amount of Light Absorbed:

Only about 1% of the light falling on the leaf surface is absorbed, the rest is transmitted or reflected.

Variations in Absorption:

The light rays of different wavelengths are not only differently absorbed by photosynthetic pigments, but are also differently effective in photosynthesis. The blue and red lights carry out more photosynthesis.

Photosystems:

The thylakoid membranes of chloroplasts contain photosynthetic pigments, organized in the form of clusters called photosystems.

Photolysis:

Light breaks water molecule (photolysis) and oxygen is released. Hydrogen atoms of water give electrons to chlorophyll and become ions.

Reduction of NADP: The electrons of chlorophyll, after the production of ATP, and hydrogen ions of water are used for the reduction of $NADP^+$ into NADPH.

Z-scheme: The whole series of light reactions is called Z-scheme due to its Z-shaped flowchart.

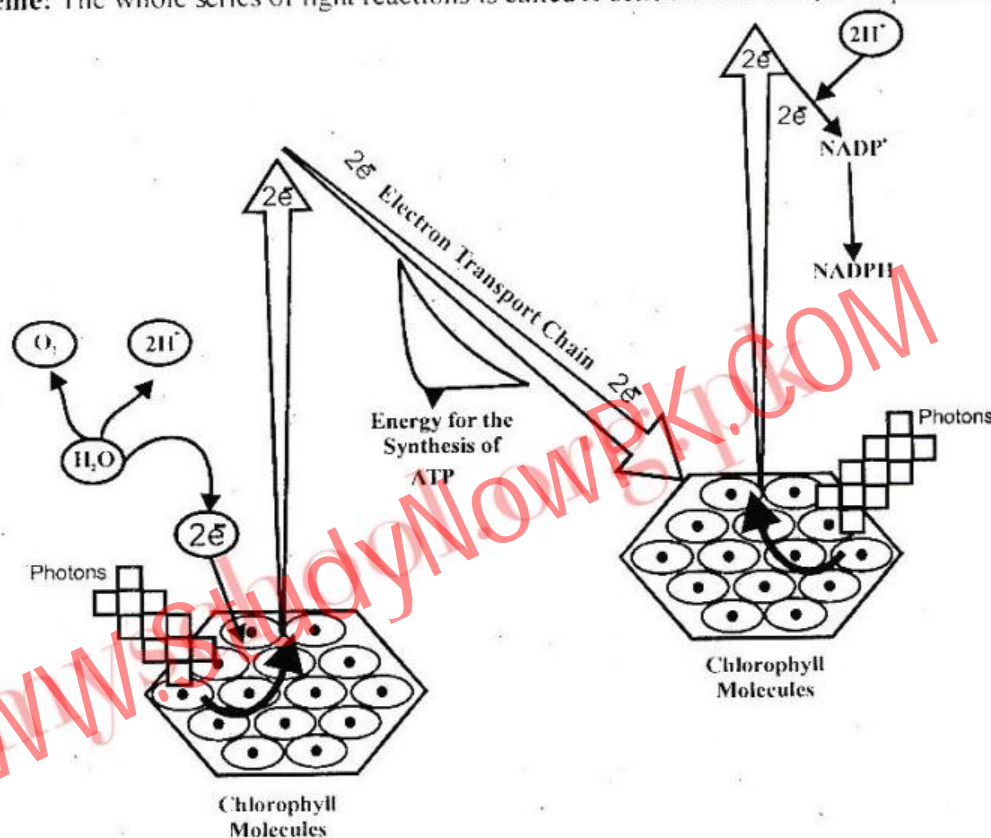



Figure: Light Reactions of Photosynthesis

Q. No. 7 Write a note on dark reactions.

DARK REACTIONS

Discovery:

The details of Dark reactions were discovered by Malvin Calvin and his colleagues at the University of California. Calvin was awarded Nobel Prize in 1961 for his work on the details of photosynthesis.

Site of Occurrence:

They take place in the stroma of chloroplasts.

Mechanism:

Formation of 6-C Compounds:

CO_2 molecules are combined with 5-carbon compounds to form temporary 6-carbon compounds.

Formation of 3-C Compounds:

Each 6-carbon compound splits into 3-carbon compounds.

TYPES OF RESPIRATION

There are two main types of respiration:

i. Aerobic respiration
ii. Anaerobic respiration

AEROBIC RESPIRATION

Definition:

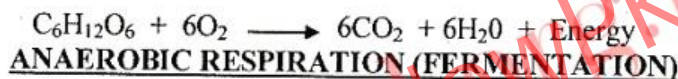
The cellular respiration occurring in the presence of oxygen is called aerobic respiration.

Mechanism:

- **First Phase:**
  In the first phase of aerobic respiration, a molecule of glucose (6-C) is broken down into two molecules of pyruvic acid (3-C).
- **Second Phase:**
  In the second phase, molecules of pyruvic acid are completely oxidized (all C-H bonds are broken) to CO_2 and water, and all energy is released.

Chemical Equation:

The overall reaction is as follows:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$$

ANAEROBIC RESPIRATION (FERMENTATION)

Definition:

The cellular respiration occurring in the absence of oxygen is called anaerobic respiration.

- In the absence of oxygen, glucose is incompletely oxidized with less amount of energy released.

Mechanism:

- **First Phase:**
  The first phase is exactly similar to that of aerobic respiration. A molecule of glucose is broken down into two molecules of pyruvic acid.
- **Second Phase:**
  In the second phase, pyruvic acid is not completely oxidized due to the absence of oxygen. It is transformed into ethyl alcohol or lactic acid. In this way, many of the C-H bonds are left unbroken in the products.

TYPES OF FERMENTATION

Anaerobic respiration or fermentation is further classified into:

i. Alcoholic fermentation
ii. Lactic acid fermentation

i. **Alcoholic Fermentation:**

In this type of anaerobic respiration, pyruvic acid is further broken down into alcohol (C_2H_5OH) and CO_2.

$$\text{Pyruvic acid} \longrightarrow \text{Ethyl alcohol} + \text{Carbon dioxide}$$

Occurrence:

It occurs in:

- Bacteria
- Yeast

Photosynthetic Pigments

Main Pigment:

Chlorophyll-a is the main photosynthetic pigment.

Accessory Pigments:

Chlorophyll-b and carotenoids are the accessory pigments.

Role of Chlorophyll:

Chlorophylls mainly absorb red and blue lights. Some wavelengths not absorbed by Chlorophyll 'a' are very effectively absorbed by accessory pigments and vice versa.

Q. No. 9 Define limiting factor. Explain some of the limiting factors in photosynthesis.

LIMITING FACTORS IN PHOTOSYNTHESIS

Definition:

Any environmental factor the absence or deficiency of which can decrease the rate of a metabolic reaction, is called limiting factor for that reaction

Important Limiting Factors:

Many factors act as limiting factors for photosynthesis like:

- Light intensity
- Temperature
- Concentration of carbon dioxide
- Availability of water

Effect of Light Intensity:

The rate of photosynthesis varies with light intensity. It decreases as the light intensity decreases and increases as the light intensity increases. However, at much higher light intensity, the rate of photosynthesis becomes constant.

Effect of Temperature:

The rate of photosynthesis decreases with decrease in temperature. It increases as temperature is increased over a limited range. But if light intensity is low, increasing the temperature has little influence on the rate of photosynthesis.

Effect of Carbon dioxide Concentration:

As carbon dioxide concentration rises, the rate of photosynthesis goes on increasing until limited by other factors. Increase in carbon dioxide concentration beyond a certain level causes the closure of stomata, and it decreases the rate of photosynthesis.

Q. No. 10 Define respiration. Discuss aerobic and anaerobic respiration.

RESPIRATION

Definition:

The cellular energy-yielding process in which food is oxidized by breaking C-H bonds through oxidation-reduction reactions to produce carbon dioxide and water, is called cellular respiration.

Oxidation-Reduction Reaction:

Cellular respiration is an oxidation –reduction reaction in which food is oxidized to CO_2 while O_2 is reduced to H_20.

Formation of Pyruvic Acid:

In glycolysis, glucose (6-C) molecule is broken into two molecules of Pyruvic acid (3-C).

ii. KREBS CYCLE

Introduction:

Krebs Cycle is named after Sir Hans Krebs who discovered this series of reactions.

Formation of Acetyl Co-A:

Before entering into Krebs Cycle, pyruvic acid is changed into 2-C compound called acetyl Co-A.

Oxidation of Pyruvic Acid:

The Pyruvic acid molecules are completely oxidized.

Formation of New Compounds:

The following new compounds are formed:

- ATP
- NADH
- $FADH_2$

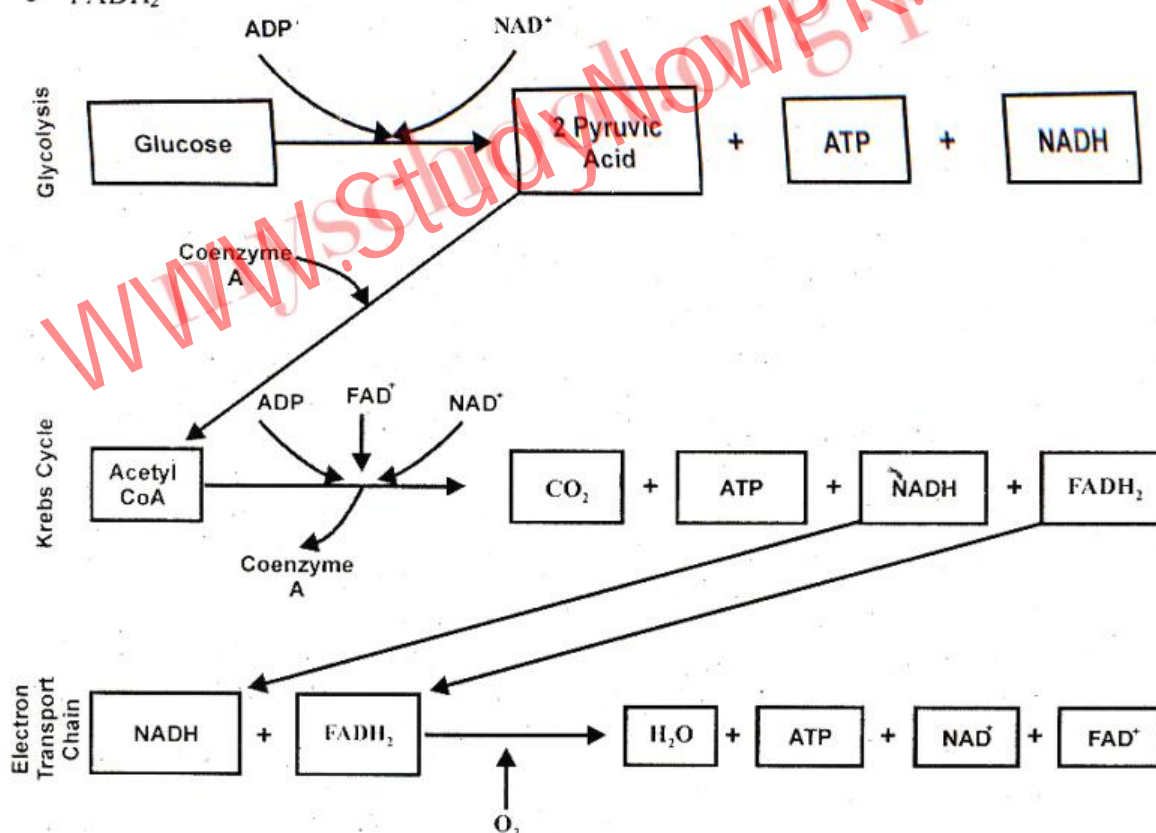



Figure: Mechanism of Respiration

ii. Lactic Acid Fermentation:

In this type of anaerobic respiration, each pyruvic acid molecule is converted into lactic acid ($C_3H_6O_3$).

Pyruvic acid ⟶ Lactic Acid

Occurrence:

It occurs in:

- Skeletal muscles of humans and other animals during extreme physical activities
- Bacteria present in milk

IMPORTANCE OF FERMENTATION

Evolution of Life:

When life evolved on Earth, the early land or water habitats did not have any supply of free oxygen (O_2). In these anaerobic conditions, early organisms respired anaerobically and got energy for their life activities.

Anaerobes:

Even today, when free oxygen is available, some organisms including some bacteria and some fungi get energy from anaerobic respiration and are called anaerobes.

During Strenuous Exercise:

- Humans can also provide energy to their skeletal muscle cells through anaerobic respiration. This happens when skeletal muscles have to work hard, (during exercise etc.) but oxygen supply cannot be increased to fulfill the demand.

Industrial Usage:

Scientists have used the fermenting abilities of fungi and bacteria for the benefit of mankind.

Examples:

- The fermenting powers of bacteria are used for making cheese and yogurt.
- Fermentation in yeasts is used in brewing and baking industries.
- Soy sauce is made by the fermentation of a fungus *Aspergillus*.

Q. No. 11 Describe Mechanism of Respiration.

MECHANISM OF RESPIRATION

The process of respiration involves a complex series of reactions.

STAGES OF AEROBIC RESPIRATION

Aerobic respiration is a continuous process but for our convenience, we divide it into three main stages:

i. Glycolysis
ii. Krebs Cycle
iii. Electron Transport Chain

i. GLYCOLYSIS

Definition:

The breakdown of glucose into pyruvic acid is called glycolysis.

Occurrence:

- Glycolysis occurs in the cytoplasm and oxygen is not required at this stage.
- It occurs in both types of respiration i.e. aerobic and anaerobic.

- Each $FADH_2$ produces 2 ATP.
- During anaerobic oxidation of glucose only 2 ATP molecules are gained as a net profit. It is because there is no Krebs Cycle and electron transport chain in anaerobic respiration.

The total net yield of ATP is 36 molecules.

Q. No. 13 Differentiate between photosynthesis and respiration.

DIFFERENCES BETWEEN PHOTOSYNTHESIS AND RESPIRATION

Characteristics	Photosynthesis	Respiration
Metabolism	Anabolism	Catabolism
Energy investment / Production	Investment of light energy to store it in the form of bond energy.	Bond energy transformed into chemical energy of ATP.
Organisms	Some bacteria, All algae, all plants	All organisms
Site of occurrence	Chloroplasts	Cytoplasm & mitochondria
Time of occurrence	Daytime only, in the Presence of light	All the time

Q. No. 14 Differentiate between aerobic and anaerobic repirstion.

DIFFERENCES BETWEEN AEROBIC AND ANAEROBIC RESPIRATION

Properties	Aerobic Respiration	Anaerobic Respiration
Presence of Oxygen	Yes	No
Net profit of ATP	36	2
Final Products	CO_2, H_2O	Lactic Acid or Ethanol + CO_2
Site of occurrence	Glycolysis in cytoplasm Krebs cycle and electron transport chain in mitochondria	Cytoplasm
Importance	Major source of energy for all organisms	Source of energy for anaerobic organisms. Source of energy for aerobic organisms in short supply of Oxygen. Source of many products (ethanol, cheese, etc.)

iii. ELECTRON TRANSPORT CHAIN

Electron transport chain is the final step of cellular respiration. It is the transfer of electron on an electron transport chain.

Release of Electrons and Hydrogen Ions:

In this step, NADH and $FADH_2$ release electrons and Hydrogen ions.

Role of Electron Carriers:

These electrons are taken up by a series of electron carriers.

Synthesis of ATP:

When electrons move through the series of electron carriers, they lose energy which is used to synthesize ATP.

Formation of Water:

At the end of chain, electrons and hydrogen ions combine with molecular oxygen and form water.

Q. No. 12 Write a note on the energy budget of respiration.

THE ENERGY BUDGET OF RESPIRATION

- Each NADH produces 3 ATP in electron transport chain.
- The NADH generated in glycolysis gives 2 ATP, because one ATP is spent to transport it across the mitochondrial membrane.

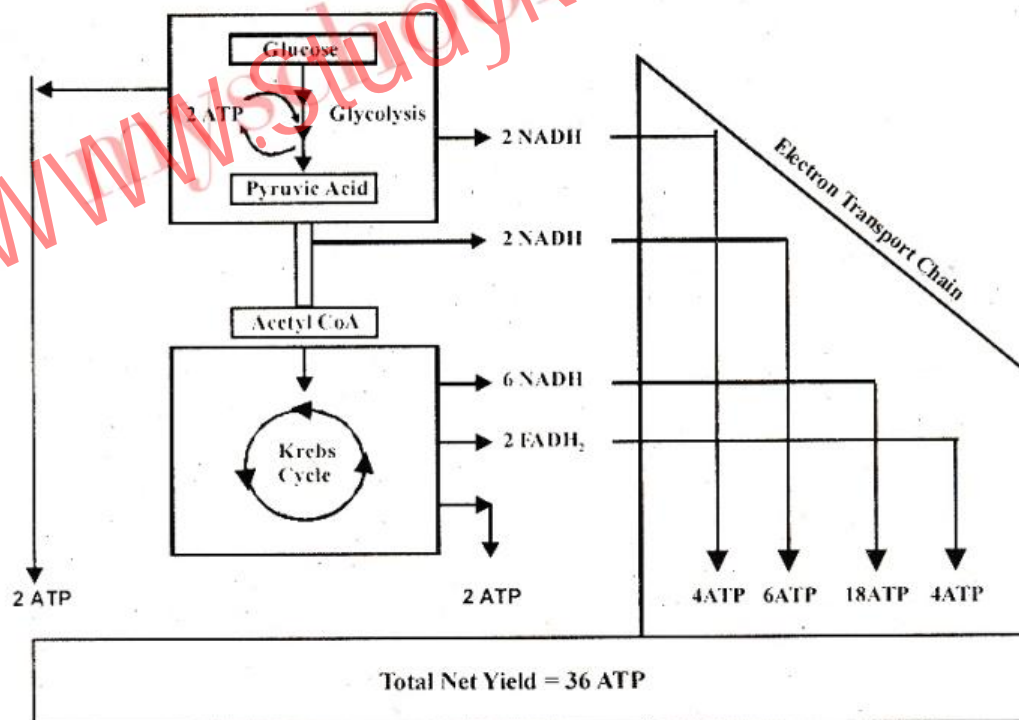



Figure: Energy Chart of Respiration

UNDERSTANDING THE CONCEPTS

(1) How would you define bioenergetics while relating it to the oxidation-reduction reactions in living systems?

Consult Short Question No. 3 & Long Question No. 2

(2) Interpret that ATP is the chief energy currency of all cells.

Consult Long Question No. 3

(3) What is the role of chlorophyll and light in photosynthesis?

Consult Long Question No. 8

(4) Outline the processes involved in photosynthesis.

Consult Long Questions No. 6 & 7

(5) State how the varying light intensity, carbon dioxide concentration and temperature affect the rate of photosynthesis?

Consult Long Question No. 9

(6) Outline the mechanism of respiration while defining glycolysis, Krebs cycle, and electron transport chain.

Consult Long Question No. 10

(7) Draw a comparison of aerobic and anaerobic respiration.

Consult Long Question No. 13

(8) How will you compare respiration and photosynthesis?

Consult Long Question No. 12

SHORT QUESTIONS

(1) **Why is it said that all life forms are dependent on photosynthesis?**

All life forms on the earth ultimately depend on each other for their energy requirements. Autotrophic organisms such as plants are capable of producing their own food by the process of photosynthesis. All other organisms are heterotrophs, i.e. depend on other organisms for their food requirements. Food is manufactured by autotrophic organisms via photosynthesis, which is used by themselves and also animals that feed on them. Autotrophic organisms lie at the base of food chain which implies that all life forms are dependent on the process of photosynthesis, directly or indirectly.

(2) **What structures and phenomena are involved in the intake of carbon dioxide and water by plants?**

Consult Long Question No. 4

(3) **In what ways the respiratory energy is used in the body of organisms?**

Consult Long Question No. 3

(4) **What is the importance of anaerobic respiration?**

Consult Long Question No. 10

THE TERMS TO KNOW

Acetyl co A: A 2-C compound which enters Krebs cycle to get oxidized.
Adenine: A nitrogenous base which commonly pairs with thiamine

REVIEW QUESTIONS

MULTIPLE CHOICE QUESTIONS

1. **In which of the following steps of respiration, CO_2 produced?**
   (a) Glycolysis (b) Krebs cycle
   (c) Electron transport chain (d) All of these
2. **Oxygen takes part in aerobic respiration in:**
   (a) Glycolysis (b) Link step between glycolysis and Krebs cycle
   (c) Krebs cycle (d) Electron transport chain
3. **When a plant was kept in darkness for many days its leaves turned yellow, why?**
   (a) Leaves could not get oxygen and so there was no photosynthesis
   (b) Leaves could not get light and so there was no respiration
   (c) Leaves could not get oxygen and so there was no respiration
   (d) Leaves could not get light and so there was no photosynthesis
4. **From which bonds of ATP molecule energy is taken?**
   (a) P-P bonds (b) C-H bonds (c) C-N bonds (d) C-O bonds
5. **In which component of leaf cells chlorophyll is present?**
   (a) Stroma (b) Thylakoids (c) Plasma membrane (d) Cytoplasm
6. **Which of these can enter Krebs cycle?**
   (a) Glucose (b) Pyruvic acid (c) Citric acid (d) Acetyl Co-A
7. **When we work hard, we suffer from muscle fatigue because muscle cells:**
   (a) Carry out aerobic respiration at a faster rate and so are tired
   (b) Carry out anaerobic respiration and so accumulate more CO_2
   (c) Carry out anaerobic respiration and so accumulate more lactic acid
   (d) Carry out aerobic respiration and so accumulate more lactic acid
8. **How many molecules of CO_2 are produced when Krebs cycle operates once?**
   (a) 01 (b) 02 (c) 03 (d) 06
9. **In which of the following metabolic processes, oxidation as well as reduction of molecules occur?**
   (a) Photosynthesis (b) Respiration (c) Both (d) None of these
10. **Chlorophyll pigment absorbs maximum light in wavelengths of:**
    (a) Green and blue (b) Green and red (c) Green only (d) Red and blue

ANSWERS:

1	b	2	d	3	d	4	a	5	b
6	d	7	c	8	b	9	c	10	d